How STEM Learning Informs Best Practice:
The UTeach Arlington and NSF Noyce Teacher Education Programs

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Establishing the Theoretical Foundation for STEM
1. What is **STEM**?
2. What is the *Purpose of Education*?
3. What is *Learning*? (i.e., How do people learn?)

Teaching to Match the Theoretical Foundation
1. What does a STEM Teacher Education program based on this theoretical foundation *look like*?
2. What are impacts of the program on STEM Teaching and Learning?
1. **What is STEM?**
   (Besides meaning “Science, Technology, Engineering and Mathematics”?)
What is STEM? Two 4th graders’ views
What is STEM?

- Observing
- Measuring
- Interpreting
- Explaining
- Discovering
- Synthesizing
- Generalizing
- Asking questions
- Designing
- Building
- Calculating
- Solving

ACTIVE PROCESS
2. What is the Purpose of Education?

What is a primary goal schools should accomplish in a child’s life?
What is the Purpose of Education?

- To develop the powers of the mind
- To be able to solve problems autonomously
- To be able to make sound decisions
- To be independent, critical thinkers

“The single most important purpose of education is to foster among students the ability... ...TO THINK.” - EPC (1961)
3. What is Learning?

That is, how do people learn?
Assimilate ↔ Accommodate ↔ Organize

Disequilibrium

Adaptation

What is Learning?

Assimilation

Organization

Accommodation

The Mental Functioning Model

- Piaget (1964)
What is Learning?

If the balloons popped the sound wouldn’t be able to carry since everything would be too far away from the correct floor. A closed window would also prevent the sound from carrying, since most buildings tend to be well insulated. Since the whole operation depends on a steady flow of electricity, a break in the middle of the wire would also cause problems. Of course, the fellow could shout, but the human voice is not loud enough to carry that far. An additional problem is that a string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems. With face-to-face contact, the least number of things could go wrong.
The Learning Cycle Matches Learning

Exploration
Facilitates Assimilation

Application
Facilitates Organization

Concept Invention
Facilitates Accommodation

disequilibrium

New
The Learning Cycle Evolved into the 5E Model

The Learning Cycle and 5-E Model

- Exploration (Engage and Explore)
- Application (Elaborate)
- Concept Invention (Explain)
- Evaluate
- NEW

DISEQUILIBRIUM
What is Learning? There is more....

**Intellectual Development:**
- Sensorimotor
- Preoperational
- Concrete operational
- Formal operational

- Piaget (1964)
Intellectual Development
Intellectual Development – Piaget

**Sensorimotor (birth – approx. 2.5 years):**
- Ego-centricism
- Object Permanence

**Preoperational (approx. 2.5 years – 7 years):**
- Cannot: general to specific/specific to general, reversibility
- Imitated play

**Concrete Operational (approx. 7 years – 11 years):**
- Conserve number, mass, liquid/solid amount, volume, area
- Difficulty with predictions and causality

**Formal Operational (approx. 11 years – adult):**
- **Scientific Reasoning**
  - **Hypothetical-deductive**
  - **Scientific-inductive**
  - **Reflective Abstraction**
  - **Proportion, Probability, Ratios, Combinatorial Reasoning,** **Control Variables**
- Can Learn without direct experience and objects, but will facilitate learning

Direct experiences and thinking/working with concrete objects advance learning and intellectual development.
What is Learning?

• Advancing children through the stages of intellectual development: *How*
  1. Experience
     - Physical
     - Logical-Mathematical
  2. Disequilibrium $\Rightarrow$ Equilibrium
  3. Social Transmission
  4. Maturation

• Content
• Structure

- Piaget (1964)
Meaningful learning theory
- Forming interrelationships among concepts
- Connecting new concepts to everyday life
- Concept mapping
  - Ausubel (1963)

Social constructivist theory
- Scaffolding
- ZPD
- Culture and language of science
  - Vygotsky (1973)
Sum: Teaching STEM should:

1. Correspond with the nature of the disciplines
   – Students engaged in **active** inquiry, problem solving, building, creating

2. Fulfill the purpose of education
   – Students engaged in learning that develops **thinking** abilities

3. Match how people learn and advance intellectual growth
   – Students consistently experiencing **assimilation** \( \rightarrow \) **accommodation** \( \rightarrow \) **organization**
Our Research on Learning

Scientific Reasoning Ability (RA) significantly predicts high school physics students’ decision to pursue college science major.

What is scientific reasoning ability?
- Proportional Reasoning
- Probability
- Controlling Variables
- Combinatorial Reasoning
- Ratios
- Logical-mathematical Reasoning
- Hypothetical-deductive Reasoning

Our research found: Scientific reasoning ability generally increased to 11th grade; declined in 12th grade and did not fully recover.

- Why?
- Senior year (avoidance of mathematics)

- Cavallo, unpublished research; Lawson, 2007
Predictors of Science Career Choice: Science Enjoyment and Scientific Reasoning


<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>R Square Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig. F Change</th>
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<td>.239</td>
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<sup>a</sup> Predictors: (Constant), ENJLRNSC

<sup>b</sup> Predictors: (Constant), ENJLRNSC, TotCTSR
What Happens to Scientific Reasoning (SR) in College?

Our Research Found:
- Biology majors – low SR
- Science majors in a non-majors physics course (Physics NP) – lowest SR
- Physics and Engineering majors in physics major course (Physics PE) – highest SR (but not fully abstract reasoners)


df (2, 281) F = 6.84, p = .001
Active Learning Increases Student Performance in STEM

SECONDARY SCIENCE AND MATHEMATICS TEACHER EDUCATION

PARTNERSHIP PROGRAM

COLLEGE OF SCIENCE – COLLEGE OF EDUCATION
FEATURES OF THE PROGRAM

• Early and continuing positive experience teaching in classrooms
  – Field experiences with inspiring teachers create satisfaction and commitment and prepare students more effectively

• First two courses offered at no cost to students
  – The whole freshman class invited to participate with tuition paid for the first courses

• Master teachers as faculty & advisors
  – Supply real life experience, guidance, and inspiration

• Internships and scholarships
  – Internships provide financial help in an educational setting, augment student training, and maintain commitment

• 4-year program where students earn their math or science bachelor’s degree along with teacher certification

• Innovative professional development courses combine content material and pedagogy
  – Focus on teaching science & math, how students learn, use of technology in teaching; research experience

• Induction support for new teachers helps insure success
### UTeach Program

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<tr>
<th>Semester 1</th>
<th>Semester 2</th>
<th>Semester 3</th>
<th>Semester 4</th>
<th>Semester 5</th>
<th>Semester 6</th>
<th>Semester 7</th>
<th>Semester 8</th>
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<tr>
<td><strong>STEP 1</strong></td>
<td><strong>STEP 2</strong></td>
<td>Knowing &amp; Learning</td>
<td>Classroom Interactions</td>
<td>Perspectives</td>
<td>Research Methods</td>
<td>Project-Based Instruction</td>
<td>Student Teaching</td>
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</table>

#### Freshman Pathway

#### Sophomore Pathway

#### Junior/Senior Pathway

### Professional Development Courses

- **Research Methods**
- **Student Teaching**
- **Knowing & Learning**
- **Classroom Interactions**
- **Project-Based Instruction**
- **Perspectives in Math & Science**

**One-hour Courses: STEP 1 & 2**

**Post-Baccalaureate Pathway**

- STEP 1 & 2
- Knowing & Learning
- Project-Based Instruction
- Perspectives

**University Provider**

- College of Science
- College of Education
- College of Liberal Arts

**(** includes field experience**)**

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**University of Texas at Arlington**
Elements of Success at UT Arlington

- Master Teachers provide a basic introduction on the Learning Cycle/5E Model in Step 1 and 2 students teach in K-8 classrooms.
- Knowing and Learning provides research and learning psychology as the foundation of the Learning Cycle/5E
- The field-based course Classroom Interactions is on diversity/equity, group learning, exceptionalities, learning differences
- Project-based Instruction has a significant field component where students develop a long term unit and teach to high school students
- In Research Methods students conduct scientific and mathematical research
- In Perspectives students learn the history and nature of science and mathematics incorporate into teaching
- Student teaching provides immersion into the classroom with guided mentors
- UTeach students are making a positive impact in the field
National Science Foundation Robert Noyce Teacher Scholarship Program Grants

First NSF grant awarded in 2008
- Supplement awarded in 2009
- Provides $10,000 per year scholarships
- Physics, Chemistry and 7-12 Math teacher candidates

Second NSF grant awarded in 2010
- Provides scholarships for Life Science, Composite Science, and Middle level Math or Science teacher candidates

Third NSF grant awarded in 2014
- Continuation for Physics, Chemistry and 7-12 Math teacher candidates
- Supplement awarded in 2016 for Life Science and Composite Science candidates
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<tr>
<th>Year</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics/Math</th>
<th>Physcial Science</th>
<th>Composite Science</th>
<th>Mathematics</th>
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<td>2011-12</td>
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<td>2012-13</td>
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The percentage of Hispanic STEM students recruited into teaching and graduating from the UTeach Arlington program is nearly double the percentage of students attending UT Arlington overall, a designated Hispanic serving institution (HSI).

<table>
<thead>
<tr>
<th>Ethnicity UTeach Arlington Graduates (N= 101)</th>
<th>%</th>
<th>Ethnicity UT Arlington Student Body (N = 51,000)*</th>
<th>%</th>
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<tbody>
<tr>
<td>Hispanic</td>
<td>41%</td>
<td>Hispanic</td>
<td>23%</td>
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<tr>
<td>Black</td>
<td>7%</td>
<td>Black</td>
<td>15%</td>
</tr>
<tr>
<td>White</td>
<td>38%</td>
<td>White</td>
<td>40%</td>
</tr>
<tr>
<td>Asian</td>
<td>14%</td>
<td>Asian</td>
<td>10%</td>
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<tr>
<td>Multiple</td>
<td>&lt; 1%</td>
<td>International</td>
<td>12%</td>
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</table>
The number of females who pursue STEM teaching in UTeach Arlington is larger than the number of males and larger than percentages of females in attendance at UT Arlington in all fields of study.

<table>
<thead>
<tr>
<th>Gender UTeach Arlington Graduates (N=101)</th>
<th>%</th>
<th>Gender UT Arlington Student Body (N = 51,000)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>73%</td>
<td>Female</td>
<td>60%</td>
</tr>
<tr>
<td>Male</td>
<td>27%</td>
<td>Male</td>
<td>40%</td>
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The average GPA of our first 101 graduates from UTeach Arlington, who earned their science or math baccalaureate degrees in the College of Science at UT Arlington along with teacher certification is higher than the GPA of all graduates in the College of Science at UT Arlington.

| Mean GPA UTeach Arlington Graduates     | 3.104| Mean GPA UTA College of Science Graduates (including Psychology)| 2.900|

*Fall 2015 from: [http://www.uta.edu/uta/about/fastfacts/](http://www.uta.edu/uta/about/fastfacts/)
• **65 of the 100 UTeach Arlington Graduates are teaching STEM in Economically Disadvantaged Schools.** This number equates to approximately 150 high school and/or middle school students taught by UTeach Arlington teachers per year or nearly 10,000 students specifically in Texas high need schools.

• **Overall, in just in the first 2 years of UTeach Arlington program graduates where each teaches approximately 150 students per academic year, between 25,000 and 30,000 K-12 students have been positively impacted.**
UTeach Across the US

National UTeach programs are growing and producing highly qualified secondary STEM teachers across the U.S. Here are the numbers.

Enrollment
UTeach programs in the U.S.: 44
National enrollment: 6,280

Graduates
Cumulative program graduates through Spring 2015: 2,676

From: https://institute.uteach.utexas.edu/uteach-impact
Outcomes of UTeach:

With collaboration and sharing common STEM teacher education foundations, practices, and goals within UTA and between UTeach programs at partner universities, UTeach is significantly:

1. Increasing numbers of teachers recruited into STEM teaching
2. Continuously improving the quality of teacher preparation and induction into teaching
3. Retaining highly qualified teachers in classrooms where they are most needed